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(54) **NARROW GAUGE HIGH STRENGTH CHOKED WET TIP MICROWAVE ABLATION ANTENNA**

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See application file for complete search history.

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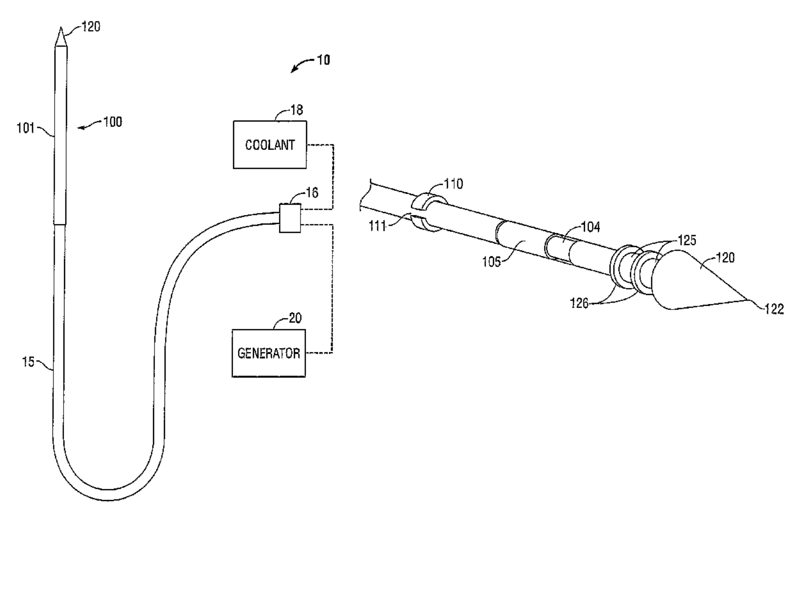
(57) **ABSTRACT**

An electromagnetic surgical ablation probe having a coaxial feedline and cooling chamber is disclosed. The disclosed probe includes a dipole antenna arrangement having a radiating section, a distal tip coupled to a distal end of the radiating section, and a ring-like balun short, or choke, which may control a radiation pattern of the probe. A conductive tube disposed coaxially around the balun short includes at least one fluid conduit which provides coolant, such as dionized water, to a cooling chamber defined within the probe. A radiofrequency transparent catheter forms an outer surface of the probe and may include a lubricious coating.

20 Claims, 6 Drawing Sheets



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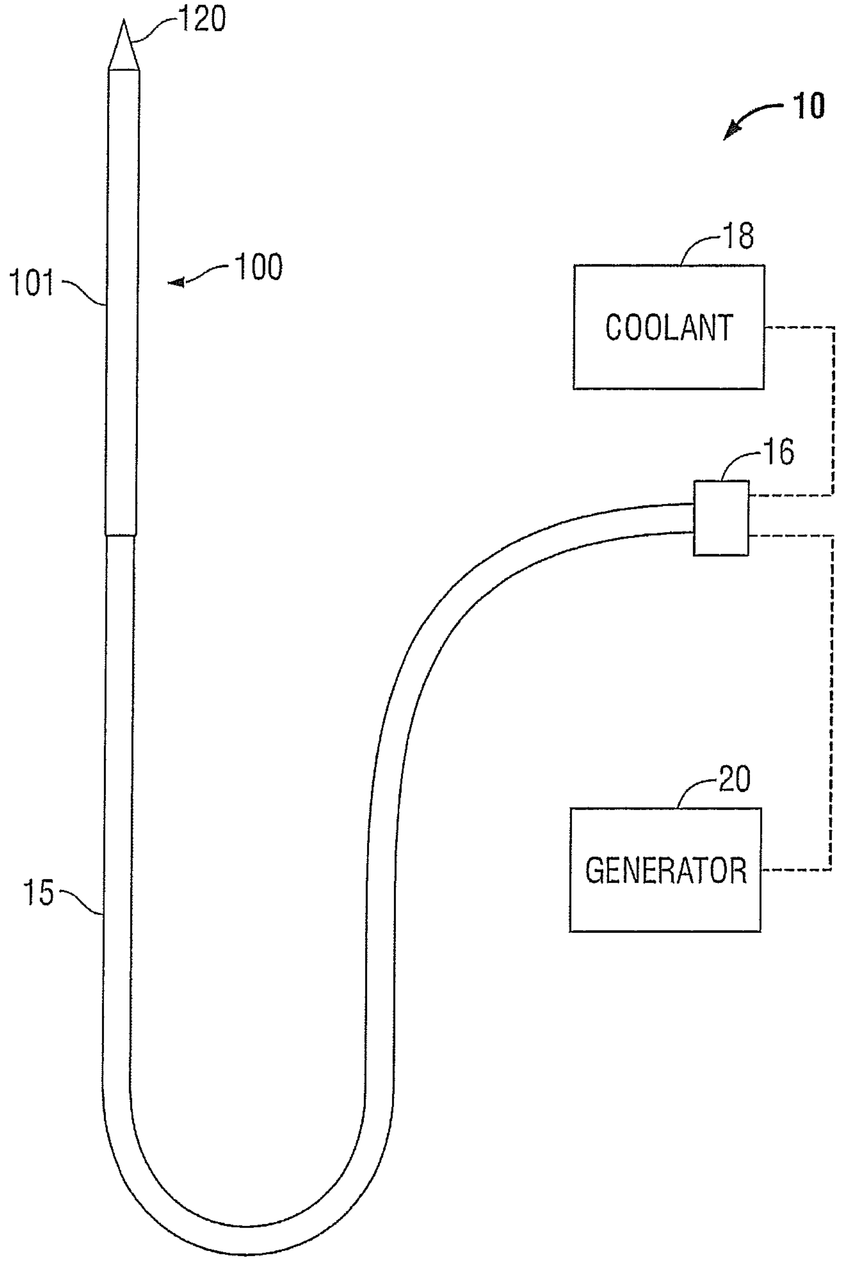


FIG. 1

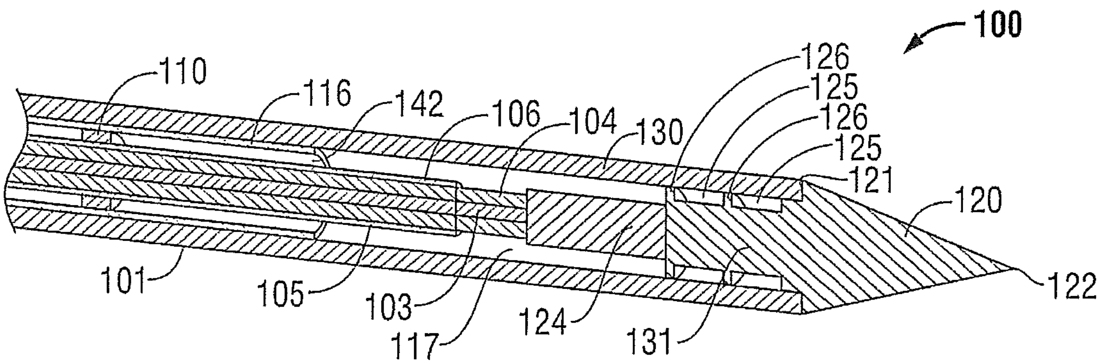


FIG. 2

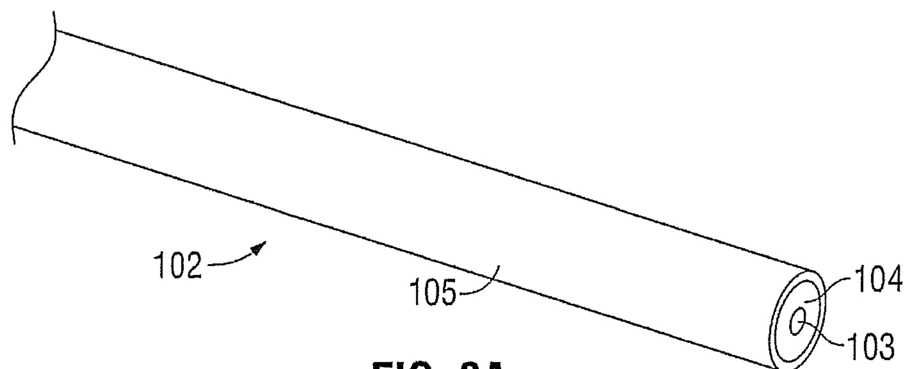
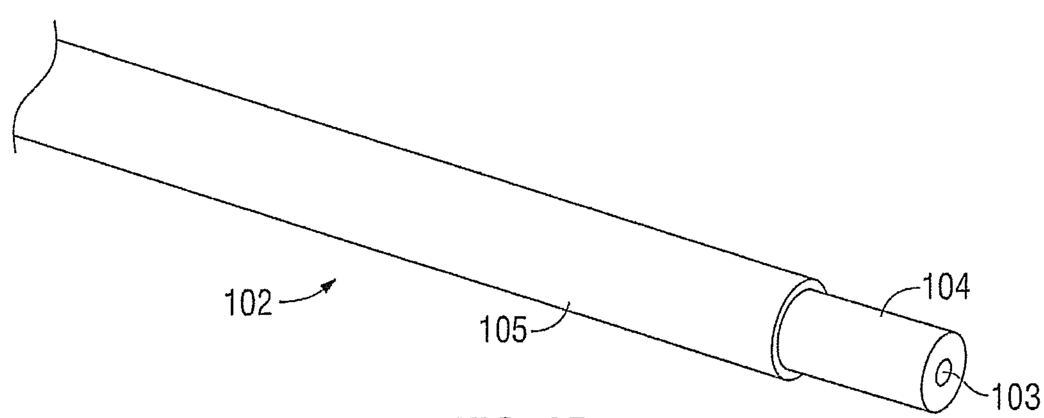


FIG. 3A



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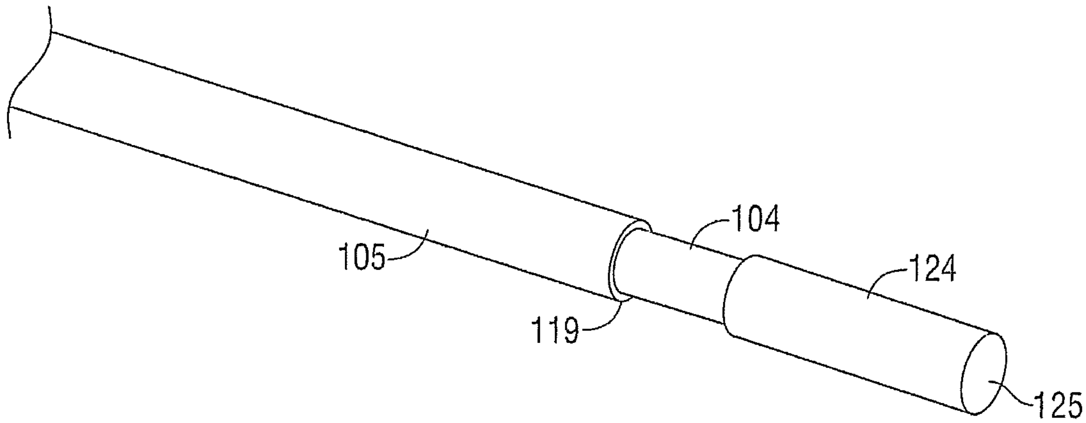

FIG. 3C

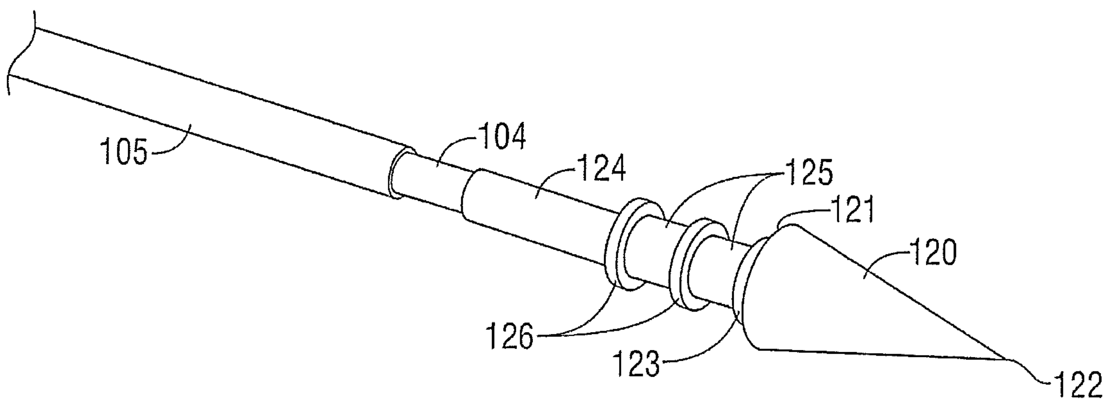

FIG. 3D

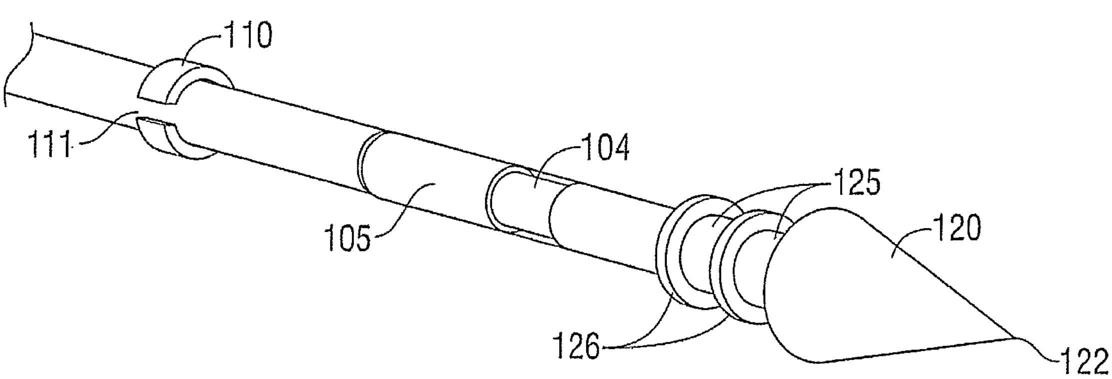

FIG. 3E

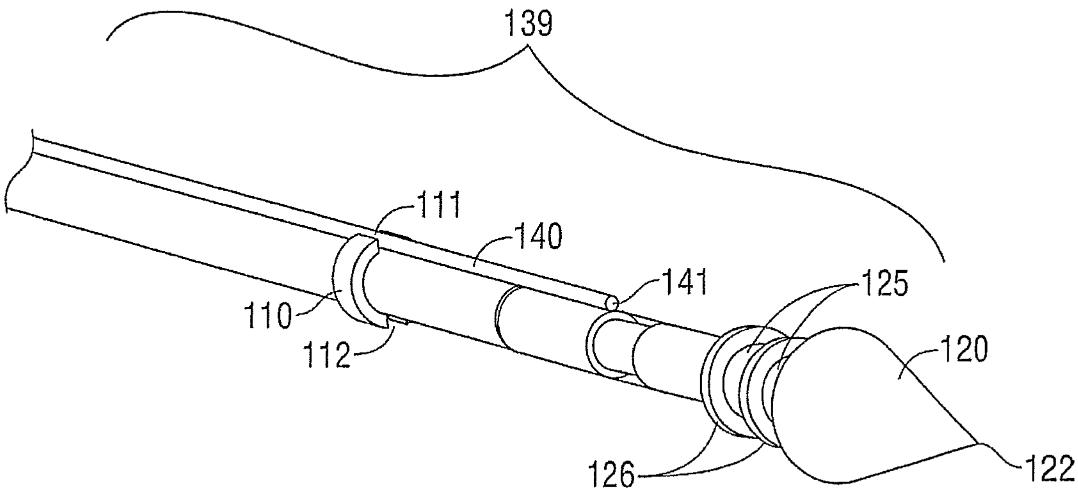
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FIG. 4A

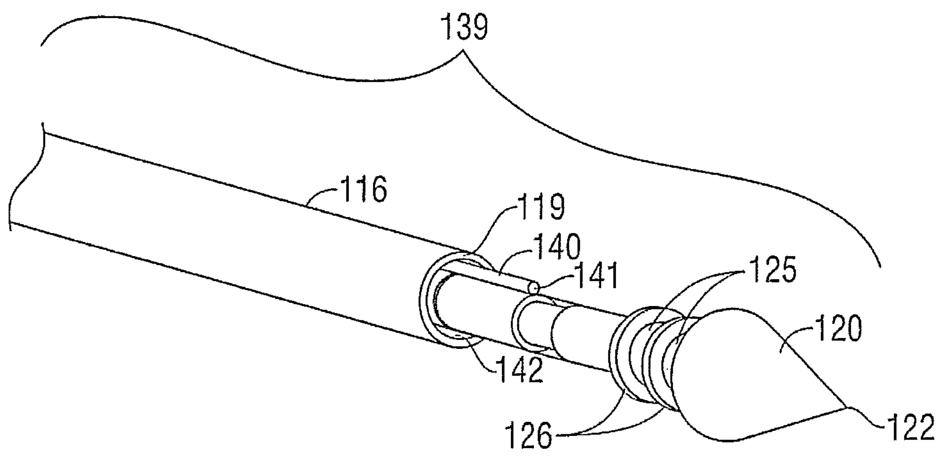
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FIG. 4B

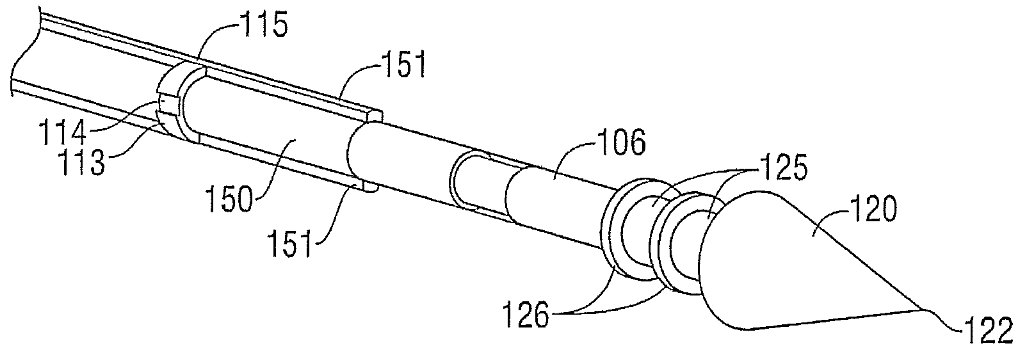

FIG. 5A

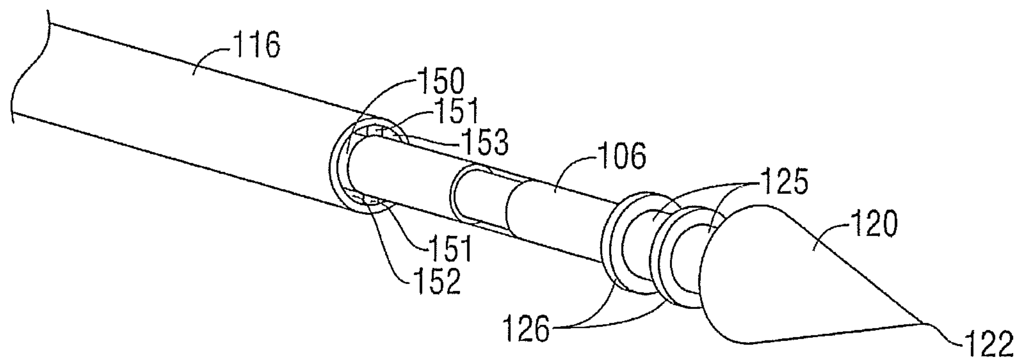

FIG. 5B

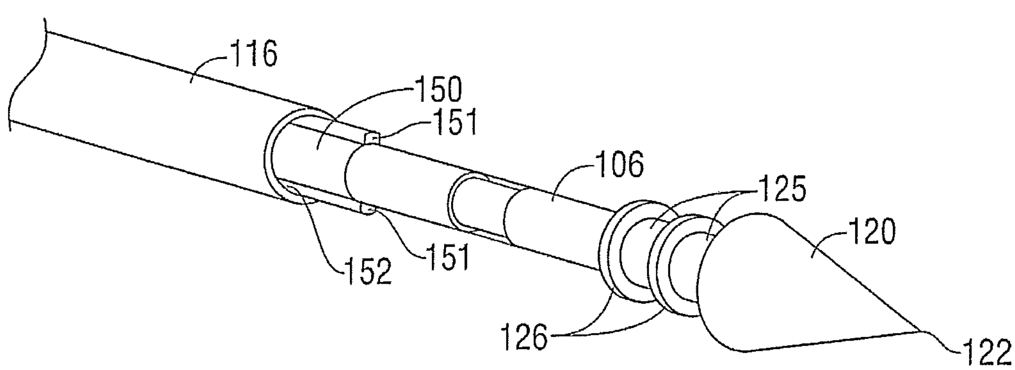

FIG. 5C

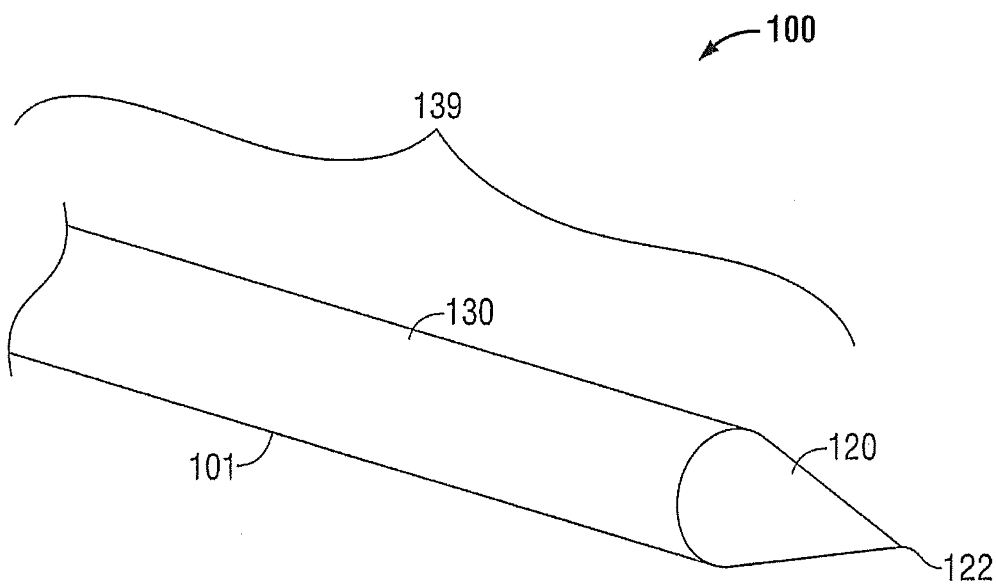

FIG. 6

NARROW GAUGE HIGH STRENGTH CHOKED WET TIP MICROWAVE ABLATION ANTENNA

CROSS-REFERENCE TO RELATED APPLICATION

This application is a Continuation of U.S. patent application Ser. No. 12/472,831, filed May 27, 2009, now U.S. Pat. No. 8,292,881, the entirety of which is hereby incorporated by reference herein for all purposes.

BACKGROUND

1. Technical Field

The present disclosure relates to systems and methods for providing energy to biological tissue and, more particularly, to a microwave ablation surgical probe having a concentric tubular structure and conical distal tip, and methods of use and manufacture therefor.

2. Background of Related Art

Energy-based tissue treatment is well known in the art. Various types of energy (e.g., electrical, ultrasonic, microwave, cryogenic, thermal, laser, etc.) are applied to tissue to achieve a desired result. Microwave energy can be delivered to tissue using an antenna probe. Presently, there are several types of microwave probes in use, e.g., monopole, dipole, and helical. One type is a monopole antenna probe, which consists of a single, elongated microwave conductor exposed at the end of the probe. The probe is typically surrounded by a dielectric sleeve. The second type of microwave probe commonly used is a dipole antenna, which consists of a coaxial construction having an inner conductor and an outer conductor with a dielectric junction separating a portion of the inner conductor. The inner conductor may be coupled to a portion corresponding to a first dipole radiating portion, and a portion of the outer conductor may be coupled to a second dipole radiating portion. The dipole radiating portions may be configured such that one radiating portion is located proximally of the dielectric junction, and the other portion is located distally of the dielectric junction. In the monopole and dipole antenna probe, microwave energy generally radiates perpendicularly from the axis of the conductor.

A typical microwave antenna has a long, thin inner conductor that extends along the axis of the probe and is surrounded by a dielectric material and is further surrounded by an outer conductor around the dielectric material such that the outer conductor also extends along the axis of the probe. In another variation of the probe that provides for effective outward radiation of energy or heating, a portion or portions of the outer conductor can be selectively removed. This type of construction is typically referred to as a “leaky waveguide” or “leaky coaxial” antenna. Another variation on the microwave probe involves having the tip formed in a uniform spiral pattern, such as a helix, to provide the necessary configuration for effective radiation. This variation can be used to direct energy in a particular direction, e.g., perpendicular to the axis, in a forward direction (i.e., towards the distal end of the antenna), or combinations thereof.

Invasive procedures and devices have been developed in which a microwave antenna probe may be either inserted directly into a point of treatment via a normal body orifice or percutaneously inserted. Such invasive procedures and devices potentially provide better temperature control of the tissue being treated. Because of the small difference between the temperature required for denaturing malignant cells and the temperature injurious to healthy cells, a known heating pattern and predictable temperature control is important so that heating is confined to the tissue to be treated. For instance, hyperthermia treatment at the threshold temperature of about 41.5° C. generally has little effect on most malignant growth of cells. However, at slightly elevated temperatures above the approximate range of 43° C. to 45° C., thermal damage to most types of normal cells is routinely observed. Accordingly, great care must be taken not to exceed these temperatures in healthy tissue.

In the case of tissue ablation, a high radio frequency electrical current in the range of about 500 MHz to about 10 GHz is applied to a targeted tissue site to create an ablation volume, which may have a particular size and shape. Ablation volume is correlated to antenna design, antenna performance, antenna impedance and tissue impedance. The particular type of tissue ablation procedure may dictate a particular ablation volume in order to achieve a desired surgical outcome. By way of example, and without limitation, a spinal ablation procedure may call for a longer, more narrow ablation volume, whereas in a prostate ablation procedure, a more spherical ablation volume may be required.

In some surgical procedures, a microwave antenna probe may be inserted percutaneously into, for example, a chest wall of a patient. During such a procedure, negotiating the probe through, for example, fibrous thoracic tissue and ribs may place undue stresses on the probe. Additionally, microwave energy may radiate into the skin, which may increase the likelihood of complications, such as skin burn.

SUMMARY

The present disclosure provides an electromagnetic surgical ablation probe having a cooled and dielectrically buffered antenna assembly. A cable provides electromagnetic energy to the probe via a coaxial conductor and/or provides coolant via a fluid conduit to improve power delivery performance and power handling, and to reduce component temperatures. Suitable coolants include deionized water, sterile water, or saline.

The probe includes two concentrically-disposed cylindrical tubes. An outer tube is a catheter formed from a radiofrequency transparent material such as an epoxy glass composite and extends from a proximal device handle to a distal tip of the probe. The catheter radiofrequency transparent material may additionally have a low electrical conductivity, or dielectric properties. In an embodiment, the catheter material may exhibit a low electrical conductivity, or dielectric properties, at a probe operating frequency (e.g., 915 MHz to 2.45 GHz). An inner tube is formed from conductive material, e.g., a metal such as stainless steel, and extends from the device handle to a proximal end of the radiating section. The inner diameter of the outer tube is substantially equal to the outer diameter of the inner tube.

A metal or plastic tip may be positioned at a distal end of the catheter. The tip may be made with trocar geometry (e.g., substantially conical) to improve ease of insertion of the probe into tissue. The tip and catheter may be coated with non-stick heat shrink material and/or lubricious coating.

An electrical connection is made between the inner metal tube and the outer conductor of the coaxial feedline at a distance of about one-quarter wavelength (γ/4) proximally from a distal end of the metal inner tube, forming a short circuited balun. Alternatively, the balun may be positioned at any odd multiple of one-quarter wavelengths (e.g., 3γ/4, 5γ/4, etc.) from a distal end of the inner metal tube. As used herein, the term wavelength refers to the wavelength of electromagnetic energy, e.g., microwave ablation energy, corresponding to an operating frequency of the disclosed antenna. The circulating coolant, which preferably has low conductivity, forms the dielectric insulator of the balun.

The radiating section of the antenna has a dipole structure. The dipole feed is constructed by opening (e.g., stripping) the coaxial outer conductor and exposing an extended dielectric and inner conductor of the coaxial feedline distally. The coaxial dielectric truncation coincides with the inner conductor increasing in diameter at a cylindrical radiating section that extends further distally toward the distal tip of the antenna. The inner conductor may be directly coupled to the tip of the antenna. The inner conductor may also flare, spiral or be loaded with disks to improve radiating performance and provide additional mechanical strength.

Notches in the balun short permit fluid circulation through the balun structure into the radiating section for cooling and dielectric buffering. Screening or mesh may also be used for the balun short. Fluid inflow and outflow control may be accomplished by either using inflow and/or outflow tubes which pass through the short circuit into the radiating section, or by using a extruded low conductivity structure to divide the cylindrical geometry into two sections for inflow and outflow. The structure may additionally center the coaxial feed line and antenna radiating structure within the catheter tubes.

A microwave ablation antenna according to the present disclosure may have advantages, such as quickly achieving a large ablation diameter, a nearly spherical ablation shape, low reflected power, cool probe shaft, with a narrower gauge needle size (15 g) for use in percutaneous procedures. The metal conductive tube may provide increased strength and stiffness, which permits difficult insertion through, for example, the chest wall. The balun short may confine most radiation to the distal tip of the probe, reducing the likelihood of complications from multiple antenna interactions, which may cause skin burn

In one embodiment, an electromagnetic surgical ablation probe according to the present disclosure includes a coaxial feedline having an inner conductor, outer conductor and a dielectric disposed therebetween. The outer conductor is truncated (e.g., stripped), whereby the inner conductor and dielectric extend beyond the outer conductor. A radiating section is coupled to the distal end of the inner conductor, and a distal tip is coupled to a distal end of the radiating section. The tip includes a generally cylindrical proximal tip extension having at least one o-ring disposed thereabout, which may help seal the coolant chamber from fluid leakage. The disclosed probe also includes a ring-like balun short disposed in electrical communication around the outer conductor, which may help control a radiation pattern of the probe. A conductive tube disposed therethrough. A radiofrequency transparent catheter joined to a proximal end of the distal tip encloses the probe and defines a coolant chamber within the probe.

Also disclosed is an electromagnetic surgical ablation system which includes a source of microwave ablation energy operably coupled to the aforementioned probe by a coaxial feedline.

The present disclosure is also directed to a method of manufacturing a microwave ablation probe that includes the steps of providing a coaxial feedline having an inner conductor, an outer conductor, and a dielectric disposed therebetween. A distal radiating section cylinder is joined to a distal end of the inner conductor and a distal tip is joined to the distal radiating section cylinder. A balun short having at least one notch defined therein is positioned on the outer conductor, and at least one fluid conduit member is positioned on an outer surface of the outer conductor such that the fluid conduit member is longitudinally disposed within the notch provided on the balun short. A conductive tube is positioned around the balun short, and radiofrequency transparent conduit is positioned over the assembly. A distal end of the radiofrequency transparent conduit is fixed to a proximal end of the distal tip.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of the present disclosure will become more apparent in light of the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. **1** shows a diagram of a microwave ablation system having an electromagnetic surgical ablation probe in accordance with the present disclosure;

FIG. **2** shows a cross sectional view of an embodiment of an electromagnetic surgical ablation probe in accordance with the present disclosure;

FIGS. **3**A-**3**E show perspective views of an embodiment of an electromagnetic surgical ablation probe at various stages of assembly in accordance with the present disclosure;

FIGS. **4**A-**4**B show views of another embodiment of an electromagnetic surgical ablation probe at various stages of assembly in accordance with the present disclosure;

FIGS. **5**A-**5**C show views of yet another embodiment of an electromagnetic surgical ablation probe at various stages of assembly in accordance with the present disclosure; and

FIG. **6** shows an external perspective view of an embodiment of an electromagnetic surgical ablation probe in accordance with the present disclosure.

DETAILED DESCRIPTION

Particular embodiments of the present disclosure will be described hereinbelow with reference to the accompanying drawings; however, it is to be understood that the disclosed embodiments are merely exemplary of the disclosure, which may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

In the drawings and in the descriptions that follow, the term "proximal," as is traditional, shall refer to the end of the instrument that is closer to the user, while the term "distal" shall refer to the end that is farther from the user.

FIG. **1** shows an embodiment of a microwave ablation system **10** in accordance with the present disclosure. The microwave ablation system **10** includes an electromagnetic surgical ablation probe **100** connected by a cable **15** to connector **16**, which may further operably connect the probe **100** to a generator assembly **20**. Generator assembly may be a source of ablation energy, e.g., microwave or RF energy in the range of about 915 MHz to about 2.45 GHz. Cable **15** may additionally or alternatively provide a conduit (not explicitly shown) configured to provide coolant from a coolant source **18** to the electromagnetic surgical ablation probe **100**.

In greater detail, and with reference to FIG. **2** and FIGS. **3**A-**3**D, an embodiment of an electromagnetic surgical ablation probe **100** includes a shaft assembly **101** having a coaxial feedline **102** disposed through the longitudinal axis of the shaft **101**. The feedline **102** includes an inner conductor **103** disposed coaxially within an outer conductor **105** and a dielectric (e.g., insulator) **104** concentrically disposed between the inner conductor **103** and outer conductor **105**. In embodiments, feedline **102** has a nominal impedance of about 50 ohms. Inner conductor **103** and dielectric **104** extend beyond outer conductor **105** at a distal end of feedline **102**.

A distal radiating section cylinder **124** is coupled to a distal end of the inner conductor **103**. A distal tip **120** is coupled at a proximal end **121** thereof to a proximal tip extension **131**. In an embodiment, proximal tip extension **131** and distal tip **120** may be integrally formed. In yet another embodiment, distal radiating section cylinder **124** may be formed from two sections wherein a proximal section is coupled to a distal end of the inner conductor **103**, and a distal section is integrally formed with proximal tip extension **131**. Inner conductor **103**, distal radiating section cylinder **124**, proximal tip extension **131** and distal radiating section cone **120** may be respectively coupled by any suitable manner of bonding, including without limitation welding, soldering, crimping, or threaded fastening. A proximal end of feedline **102** may be operably coupled to a generator **20** configured to generate microwave ablation energy in the range of about 800 MHz to about 5 GHz.

In one embodiment, distal tip **120** has a generally conical shape having an apex at a distal end **122** thereof. However, embodiments are envisioned wherein distal tip **120** may have any shape, including without limitation, a cylindrical, rounded, parabolic, flat, knife-like, and/or flared shape. Distal tip **120** may be formed from any suitable material, include metallic, nonmetallic, and polymeric materials.

With reference particularly to FIG. **3**D, at least one o-ring **126** is positioned around distal radiating section cylinder **124** and/or a distal segment thereof that is integrally formed with distal tip **120**. O-ring **126** may be formed from any suitable heat-resistant material, and may additionally or alternatively be integrally formed with distal radiating section cylinder **124** and/or a distal segment thereof that is integrally formed with distal tip **120**. An outer diameter of o-ring **126** is dimensioned to provide a fluid seal with an inner diameter of catheter **130** as illustrated in FIGS. **4**C and **5**B and as will be described in greater detail below. Distal tip **120** may include at a proximal end thereof a shoulder **123** that has an outer diameter dimensioned to couple with an inner diameter of conductive tube **116**. Additionally or alternatively, shoulder **123** may include an o-ring **126**. In one embodiment, a sealant (not explicitly shown) such as elastomeric polymer or epoxy may be included in a region **125** adjacent to o-ring **126** and/or shoulder **123**.

Referring again to FIG. **2**, and to FIG. **6**, a tubular catheter **130** extends proximally from a proximal end **121** of distal tip **120**. Catheter **130** has an inner diameter substantially equal to the outer diameter of a conductive tube **116** and of shoulder **123**. An outer diameter of catheter **130** has an outer diameter that substantially corresponds to that of the base (e.g., proximal) diameter of distal tip **120**. Catheter **130** is formed from radiofrequency transparent material. Catheter **130** may be formed from material having a low electrical conductivity, or dielectric properties. In an embodiment, the probe **130** material may have low electrical conductivity, or dielectric properties, in a probe operating frequency range, e.g., an operating range of about 915 MHz to about 2.45 GHz. Catheter **130** may be formed from composite material, such as without limitation, epoxy glass composite, carbon fiber, and the like. In an embodiment, catheter **130** may not be completely transparent to radiofrequency energy, and instead may be nearly or substantially transparent. In use, a dielectric constant of catheter **130** may aid in matching the combined impedance of the probe and tissue in contact therewith to the impedance of coaxial feedline **102**, which in turn may improve energy delivery to tissue. Additionally, the low electrical conductivity of catheter **130** may reduce undesired reflection of radiofrequency and/or microwave energy.

The disclosed probe includes a balun short **110** that is coaxially disposed around a outer conductor, located proximally of a distal end **119** of outer conductor as best seen in FIG. **3**E. Advantageously, balun short **110** may be positioned a quarter wavelength distance from a distal end **119** of conductive tube **116**. Balun short **110** may be formed from conductive material (e.g., metallic or conductive polymeric material) to form an electrical connection between outer conductor **105** and conductive tube **116**. Balun short **110** includes at least one notch **111** defined therein which may assist in cooling the probe **100** during use. A coolant chamber **117** may be defined by the inner surface of catheter **130**, o-ring **126**, balun short **110**, and the outer surface of outer conductor **105**. Balun short **110** may additionally or alternatively be formed from conductive screen, mesh or woven materials. In embodiments, cooling may be achieved passively by thermal convection (e.g., ventilation provided by the at least one notch **111**), or actively by the flow of coolant within the probe **100** as will now be described. Catheter **130** and/or distal tip **120** may include a coating (not explicitly shown), such as a lubricious (e.g., non-stick) coating formed from polytetrafluoroethylene (a.k.a. PTFE or Teflon®, manufactured by the E.I. du Pont de Nemours and Co. of Wilmington, Del., USA), polyethylene terephthalate (PET), or the like. Additionally or alternatively, catheter **130** and/or distal tip **120** may include a heat shrink coating, such as polyolefin tubing or any suitable heat-shrink material.

In an embodiment illustrated in FIGS. **4**A and **4**B, an inflow tube **140** is disposed longitudinally along an outer surface of outer conductor **105**. Inflow tube **140** includes an open distal end **141** that is configured to deliver coolant fluid to a coolant chamber **117**. Inflow tube **140**, at a proximal end thereof (not explicitly shown), may be in fluid communication with a coolant source **18**, such as without limitation a coolant pump or drip bag. Any suitable medium may be used as a coolant. In embodiments, deionized water, sterilized water, or saline may be used as a coolant. In one aspect, the coolant may have dielectric properties which may provide improved ablation volume and shape, and/or may provide improved impedance matching between the probe **100** and tissue. During use, coolant flows distally though inflow tube **140** and is introduced into coolant chamber **117** at the open distal end **141** of inflow tube. As best seen in FIG. **4**A, inflow tube **140** is positioned within notch **111** defined in balun short **110**. Balun short **110** includes an outflow notch **112** through which coolant may exit coolant chamber **117**.

In another embodiment illustrated in FIGS. **5**A, **5**B, and **5**C, a rib **151** is longitudinally disposed between an outer surface of outer conductor **105** and conductive tube **116** to concentrically position coaxial feedline **102** within conductive tube. Rib **151** is preferably formed from a low-conductivity or insulating material. A second longitudinal rib **151** may be included to form an inflow channel **152** and an outflow channel **153**. The ribs **151** may radially opposed (e.g., offset approximately 180° apart as indexed with reference to the circular cross-section of coaxial feedline **102** and/or conductive tube **116**) and dimensioned to define an inflow channel **152** and outflow channel **153** between conductive tube **116** and outer conductor **105** of substantially similar size. Embodiments are envisioned within the scope of the present disclosure wherein ribs **151** are positioned more, or less, than 180° apart. Embodiments having three or more ribs are contemplated, wherein three or more channels (not explicitly shown) are formed. The additional channels may be used to circulate different types of coolant, having, for example, differing dielectric and/or thermal properties. Additionally, the channels may deliver to the probe, and/or to tissue, medicaments, bioadhesives, radioisotopes, and/or other useful therapeutic compounds. With particular reference to FIG. **5**A, the present embodiment includes a balun short **113** having rib notches **115** that are adapted to position and retain ribs **151**. Balun short **113** additionally includes coolant notches **114** that are adapted to facilitate the flow of coolant past balun short **113**, as will be readily appreciated. In embodiments, balun short **113** may be constructed from perforated metal, metal mesh, or screen material.

A method of manufacturing a high-strength microwave ablation probe **100** is shown in accordance with the present disclosure with reference now to FIGS. **3A-3E**. It is to be understood that the steps of the method provided herein may be performed in combination and in a different order than presented herein without departing from the scope and spirit of the present disclosure.

With reference to FIG. **3**A, a coaxial feedline **102** is provided having an inner conductor **103**, a dielectric **104** and an outer conductor **105**. As shown in FIG. **3**B, the inner conductor **103** and dielectric **104** is extended beyond outer conductor **105** at a distal end thereof. In one embodiment of the disclosed method, a stripping tool may be used to trim a distal portion of outer conductor **105** to expose inner conductor **103** and dielectric **104**. As seen in FIG. **3**C, a distal radiating section cylinder **124** is provided and affixed to inner conductor **103** by any suitable manner of attachment, for example and without limitation, by laser welding. As shown in FIG. **3**D, a distal tip **120** is provided, having a generally conical shape and including a proximal tip extension **131** that is dimensioned to couple to a distal surface **129** of distal radiating section cylinder **124**. Distal tip **120** is affixed to distal radiating section cylinder **124** by any suitable manner of bonding, such as without limitation, by laser welding or threaded fastener. At least one o-ring **126** is positioned on proximal tip extension **131**. In a step illustrated in FIG. **3**E, a balun short **110** having a notch **111** defined therein is positioned and electrically coupled to outer conductor **105**.

In an embodiment best illustrated in FIG. **4**A, an inflow tube **140** is longitudinally disposed along outer conductor **105** and positioned within notch **111**. As seen in FIG. **4**B, a conductive tube **116** is positioned over the assembly **139**. A distal end **119** of conductive tube **116** is positioned distally of balun short **110** at a distance of about one-quarter wavelength therefrom. In a step depicted in FIG. **6**, catheter **130** is positioned over the assembly **139** and joined to a proximal end **121** of tip **120**. An inner diameter of catheter **130** may be dimensioned to engage an outer diameter of shoulder **123**. Additionally or alternatively, a sealant (not explicitly shown) may be applied to region **125** adjacent to o-ring **126** and/or shoulder **123**.

In an embodiment best illustrated in FIG. **5**A, a balun short **113** having two pairs of radially opposed notches **114**, **115** defined therein is positioned and electrically coupled to outer conductor **105**. A pair of ribs **151** are longitudinally positioned within a respective notch **115**. A distal end **119** of conductive tube **116** is positioned distally of balun short **110** at a distance of about one-quarter wavelength therefrom. In a step depicted in FIG. **6**, catheter **130** is positioned over the assembly and joined to a proximal end **121** of tip **120**. An inner diameter of catheter **130** may be dimensioned to engage an outer diameter of shoulder **123**. Additionally or alternatively, a sealant (not explicitly shown) may be applied to region **125** adjacent to o-ring **126** and/or shoulder **123**.

The described embodiments of the present disclosure are intended to be illustrative rather than restrictive, and are not intended to represent every embodiment of the present disclosure. Further variations of the above-disclosed embodiments and other features and functions, or alternatives thereof, may be made or desirably combined into many other different systems or applications without departing from the spirit or scope of the disclosure as set forth in the following claims both literally and in equivalents recognized in law.

What is claimed is:

1. An ablation probe, comprising:

a coaxial feedline having an inner conductor, an outer conductor disposed coaxially about the inner conductor, and a dielectric disposed therebetween, wherein the inner conductor and dielectric extend beyond the outer conductor at a distal end thereof;

a balun short disposed in electrical communication around the outer conductor and including a first longitudinal notch and at least one second longitudinal notch defined therein;

a conductive tube disposed coaxially around the balun short; and

at least one fluid conduit defined longitudinally within the conductive tube, the fluid conduit including an inflow tube disposed longitudinally along the outer conductor and positioned at least partially within the first notch.

2. The ablation probe in accordance with claim **1**, wherein the balun short includes at least two first notches defined therein adapted to receive a corresponding number of rib members and includes at least two second notches defined radially therebetween, wherein the at least two rib members are disposed longitudinally along the outer conductor and positioned at least partially within the respective notches thereof to define at least two fluid conduits within the conductive tube.

3. The ablation probe in accordance with claim **1**, wherein a distal end of the conductive tube is positioned about one quarter wavelength distally from the balun short.

4. The ablation probe in accordance with claim **1**, wherein the balun short is formed from material selected from the group consisting of conductive screen material, conductive mesh material, and conductive woven material.

5. The ablation probe in accordance with claim **1**, wherein the balun short is formed from material selected from the group consisting of conductive metallic material and conductive polymeric material.

6. The ablation probe in accordance with claim **1**, further comprising a radiating section having a proximal end operably coupled to a distal end of the inner conductor.

7. The ablation probe in accordance with claim **6**, further comprising a distal tip coupled to a distal end of the radiating section, wherein the distal tip includes a generally cylindrical proximal tip extension having at least one o-ring disposed thereabout.

8. The ablation probe in accordance with claim **7**, further comprising a catheter coaxially disposed around the conductive tube, wherein a distal end of the catheter is joined to a proximal end of the distal tip to define a coolant chamber therein.

9. An ablation system, comprising:

a source of microwave ablation energy;

a coaxial feedline operatively coupled to the source of microwave ablation energy, wherein the coaxial feedline includes an inner conductor, an outer conductor disposed coaxially about the inner conductor, and a dielectric disposed therebetween, wherein the inner conductor and dielectric extend beyond the outer conductor at a distal end thereof;

a balun short disposed in electrical communication around the outer conductor and including a first longitudinal notch and at least one second notch defined therein;

a conductive tube defined coaxially around the balun short; and

at least one fluid conduit defined longitudinally within the conductive tube, the fluid conduit including an inflow tube disposed longitudinally along the outer conductor and positioned at least partially within the first notch.

10. The ablation system in accordance with claim **9**, further comprising a source of coolant in fluid communication with the at least one fluid conduit.

11. The ablation system in accordance with claim **9**, wherein the balun short includes at least two first notches defined therein and at least two second notches defined radially therebetween; and

at least two rib members disposed longitudinally along the outer conductor, wherein each rib member is positioned at least partially within a first notch to define at least two fluid conduits within the conductive tube.

12. The ablation system in accordance with claim **9**, wherein a distal end of the conductive tube is positioned about one quarter wavelength distally from the balun short.

13. The ablation system in accordance with claim **9**, wherein the balun short is formed from material selected from the group consisting of conductive screen material, conductive mesh material, and conductive woven material.

14. The ablation system in accordance with claim **9**, wherein the balun short is formed from material selected from the group consisting of conductive metallic material and conductive polymeric material.

15. The ablation system in accordance with claim **9**, further comprising a radiating section having a proximal end operably coupled to a distal end of the inner conductor.

16. The ablation system in accordance with claim **15**, further comprising a distal tip coupled to a distal end of the radiating section, wherein the distal tip includes a generally cylindrical proximal tip extension having at least one o-ring disposed thereabout.

17. The ablation system in accordance with claim **16**, further comprising a catheter coaxially disposed around the conductive tube, wherein a distal end of the catheter is joined to a proximal end of the distal tip to define a coolant chamber therein.

18. The ablation system in accordance with claim **9**, wherein the catheter is formed from radiofrequency transparent material having an electrical property selected from the group consisting of a low electrical conductivity and a dielectric.

19. The ablation system in accordance with claim **9**, wherein a distal end of the inflow tube is in fluid communication with the coolant chamber.

20. A method of manufacturing an ablation probe, comprising the steps of:

providing a coaxial feedline having an inner conductor, an outer conductor, and a dielectric disposed therebetween;

positioning a balun short on the outer conductor;

forming a notch defined longitudinally in the balun short;

positioning at least one fluid conduit member on an outer surface of the outer conductor, wherein the conduit member is longitudinally disposed within the notch;

positioning a conductive tube around the balun short.

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